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Assessment of Commercial Alternatives to the C4 Mask For Use in Moderate to High Risk Biological Scenarios

BY

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ABSTRACT

There are an increasing number of possible scenarios for the Canadian Forces where protection from a biological threat is required. These scenarios extend beyond the threat of biological warfare and include contingency operations, such as peacekeeping and humanitarian operations. Many of the diseases we consider as potential biological warfare threats exist as endemic diseases in many parts of the world. While the Canadian Forces C4 mask would provide protection against aerosolized infectious material in these situations, the use of the mask could degrade operational performance and the degree of protection provided could be far in excess of the risk. In this study we have assessed a variety of commercially available alternatives to the C4 that could provide an appropriate degree of protection relative to the risks involved, while presenting a lower logistical and operational burden. Overall, the 3M High Efficiency Respirator with exhalation port No. 9970 appears to be an ideal alternative to the C4 in such situations.

EXECUTIVE SUMMARY

There are an increasing number of possible scenarios for the Canadian Forces where protection from a biological threat is required. These scenarios extend beyond the threat of biological warfare and include contingency operations, such as peacekeeping and humanitarian operations. Many of the diseases we consider as potential biological warfare threats exist as endemic diseases in many parts of the world. While the Canadian Forces C4 mask would provide protection against aerosolized infectious material in these situations, the use of the mask could degrade operational performance and the degree of protection provided could be far in excess of the risk.

In this study we have assessed nine commercially available masks using a panel of 5 volunteers. Protection factors were determined using a PortaCount device, normally used in the fit testing of the C4 mask at DRES. The PortaCount device determines a protective factor for the C4 mask by comparing the relative concentrations of ambient particles in the air and within the mask itself, while the person being fitted is wearing the mask. With the C4 mask the drinking tube is used as a sampling port to allow air sample to be collected from within the mask. For the other masks tested here, a small hole was made in the mask to allow insertion of a small piece of Tygon tubing which was then sealed into place.

Results showed that, contrary to the popular expectation, surgical masks provide very little protection against aerosol particles. Other types of dust/mist masks provided far more protection than did surgical masks, but not to the point where they might be considered as significant protection against aerosolized infectious material.

HEPA (High Efficiency Particulate) style masks were found to provide a reasonable degree of protection. Overall the authors felt that the 3M High Efficiency Respirator with exhalation port No. 9970 provided a combination of protection, comfort, ease of use, and low cost that would make it an ideal alternative to the C4 in some types of contingency operations where Canadian Forces personnel were exposed to aerosolized infectious material from environmental or medical sources.

TABLE OF CONTENTS

INTRODUCTION

In 1991, during the course of OP Friction and the Canadian contribution to the Gulf War, DRES responded to many requests for information and analysis concerning safe operations in a chemical and biological threat environment. One such request from the Directorate of Medical Operations, required a quick study to determine if surgical masks could be worn during the sleep cycle, in place of the C4 mask, to provide some protection from a covert BW attack. The study was completed and showed that these masks, contrary to popular belief, provided little protection versus an aerosol challenge. These data assisted DMO-3 to decide against recommending these masks for use by CF personnel.

DRES has received several inquiries since 1991 concerning the effectiveness of commercial masks and facelets. There are an increasing number of possible scenarios where protection from a biological threat is required. These scenarios extend beyond the BW threat and include contingency operations. The recent OP Griffon initiative, the experience of personnel in OP Passage, the medical humanitarian operation in Rwanda in 1995, and the current humanitarian mission to Zaire (at the time of writing, Nov 1996), provide examples where CF personnel require protection from aerosolized disease causing organisms. In these situations the use of a surgical mask would provide insufficient protection while the use of a C4 mask, while protective, could be a detriment for other reasons. In these non-BW scenarios an effective alternative is required, providing protection appropriate to the risk while minimizing any degradation of performance due to the mask itself.

MATERIALS AND METHODS

The surgical and industrial masks tested in this study included. 1. 3M Non-toxic Particle Mask No. 8500; 2. 3M Dust and Mist respirator No. 8710; 3.Technol Classic Surgical Mask No. 48200; 4. Canadian C4 Military gas mask; 5. Precept Comfort-cone Fluid resistant Surgical mask Fiberglass Free No. 65-3333; 6. 3M Nuisance Level Acid Gas Respirator 9915; 7. 3M Dust/Mist Respirator 9900; 8. UVEX Better Breathing Respirator HEPA-Tech 3010; 9. Dual cartridge Respirator half mask, silicone (Lab Safety Supply) 10. Military

facelet NBC L1A1 (NSN 4240-00-226-3109) and 11. 3M High Efficiency respirator with exhalation port No. 9970.

For the initial testing , five DRES volunteers served as test subjects for each of the masks. Masks that clearly had a poor fit (eg. surgical masks) were also tested with the mask taped onto the face (with surgical tape) to eliminate any air leakage along the edge of the mask. This variation of the experiment demonstrated the relative amount of edge leakage for these masks. Masks with a form fitting design and a good seal were not tested with the tape method.

Further testing was done with the 3M No. 9970 mask in an additional 17 volunteers. Each volunteer had their face measured (chin to bridge of nose) as is done in fitting the C4 mask to determine if this measurement was predictive of the necessary size of a commercial mask.

Mask testing was conducted using a Porta-Count device (TSI Inc., St. Paul MN, USA). This device is normally used at DRES for testing the fit of the C4 mask by comparing particle counts (0.02 - 1 μm size range) in the ambient air against those within the mask itself. The measurement is taken while the individual being fitted wears the mask. The ratio of these two concentrations becomes the "fit factor" or "protection factor". In the case of the C4 mask, the drinking tube is used as a sampling port to sample the air within the mask. For the other masks tested, a short length of Tygon™ tubing was inserted through a hole in the mask in the nose/mouth region and the hole sealed with GE RTV 108 Silicone Rubber Adhesive Sealant™ (GE Silicones Canada, Pickering, Ontario).

RESULTS

The results of the preliminary tests are presented in Tables 1 to 11 for each of the 11 masks tested. Since every human face is slightly different, the tables include the results for each person tested as well as an average result from all those tested. Table 12 is a summary of the data with side by side comparison of the different types of masks from the preliminary test series.

In Table 13, a summary of the followup testing is presented for the 3M Model 9970. Each of the 22 volunteers was tested with both size masks (Medium and Large) and only data from the better fitting mask is included in this table. Fifteen of the volunteers had a better fit with the medium size mask and the remaining 7 had a better fit with the large size mask.

DISCUSSION

It is clear from the results that there is considerable variation in the protective value of the different types of masks. The common types of surgical masks offer very little in the way of respiratory protection to the user (Tables 1 and 3). The non-toxic particle mask seen in Figure 2 was similar in performance to the surgical masks (Table 2). The cone shape type of surgical and non-toxic dust masks conformed well to the face and taping the edges of the mask made only a slight improvement to the protection factor. Edge leakage was considerably greater in the conventional type of surgical mask, which showed a 72% improvement in protection factor when the edges were taped to the face.

The military facelet (Figure 3) showed very little protection (Table 3) against particulates. This facelet was designed to provide some protection against chemical vapours and was not intended for protection against particulate materials.

The commercial masks shown in Figures 5-7 provided a significantly greater degree of protection than surgical masks (Tables 5 to 7), however the protection factors seen were not sufficient to provide real protection against aerosolized infectious materials, nor were they designed for such protection.

The commercially available masks presented in Figures 8-10 are all designated as HEPA (High Efficiency Particulate) type masks. All provided a sufficient degree of protection (Tables 8-10) against the concentrations of infectious aerosols expected under non-biological warfare attack scenarios.

The actual degree of protection that would be obtained by an individual is dependant upon the fit of the mask. As can be seen from the data in Table 9, in which volunteers wore both the Large and Medium size masks, incorrect mask size can make a huge difference in the protection factor obtained. Volunteer 5, for example obtained a protection factor of 2360 while wearing a Medium mask but only a protection factor of 98 while wearing a Large mask.

An extended study of the 3M No. 9970 mask using the C4 mask sizing device as a predictor of best fit indicated that the C4 mask sizing device was not predictive (data not shown).

The C4 mask was designed to protect CF personnel in the CBW battlefield. The protection factors are very high, as noted in Table 11. For scenarios other than the BW battlefield, including high risk situations such as handling infectious patients or biological wastes and sanitizing buildings suspected of harbouring endemic threat agents, the C4 may be inappropriate because of the unnecessary operational performance liabilities, logistical burden, cost and protection factors. In addition, in situations where the CF must deal with civilians in a non-BW environment, the visual impact of a C4 mask on the civilians must be taken into consideration. Civilians might perceive the mask as frightening and/or threatening and this perception could interfere in the process of the CF carrying out a peacekeeping or humanitarian mission.

The masks recommended below may be acceptable alternatives for operational commands to consider.

RECOMMENDATIONS

From the available commercial masks tested the authors believe that the 3M High Efficiency Respirator No. 9970 (with exhalation port) would be the most suitable in CF operations where there is a medium to high risk of exposure to infectious aerosols. The mask provides a reasonable and appropriate degree of protection (far greater than conventional surgical masks), is comfortable to wear, compatible with most types of eyeglasses, and is generally

similar in appearance to a surgical mask (ie. non-threatening to most people). The 3M No. 9970 suffers from one possible drawback. It contains a natural latex rubber to which some individuals may be allergic, as was the case with one of our 22 volunteers, resulting in a skin rash.

As a secondary choice, Uvex Better Breathing Respirator would be a good alternative. It provides the same degree of protection but does not contain any natural latex, eliminating the problems of skin allergies. The lack of an exhalation port made the mask slightly less comfortable to wear and the height of the nose on this mask could interfere with some types of eyeglasses.

SUMMARY

Based on fit testing studies conducted on volunteers there are two commercially available masks that could be used by the CF to protect personnel against infectious aerosols in moderate to high risk situations. The best choice overall is the 3M High Efficiency Respirator No. 9970 (with exhalation port) and an alternative is the Uvex Better Breathing Respirator. These masks are inexpensive, easy to use and would provide less performance degradation than a C4 mask while still providing a degree of protection appropriate to the risk. The visual impact of an individual wearing an industrial mask such as these (purple or white HEPA style half-masks) is little different from someone wearing a surgical mask. This is not the case with a C4 mask which might be perceived in a negative way by civilians encountered during contingency and other operations.

Figure 1

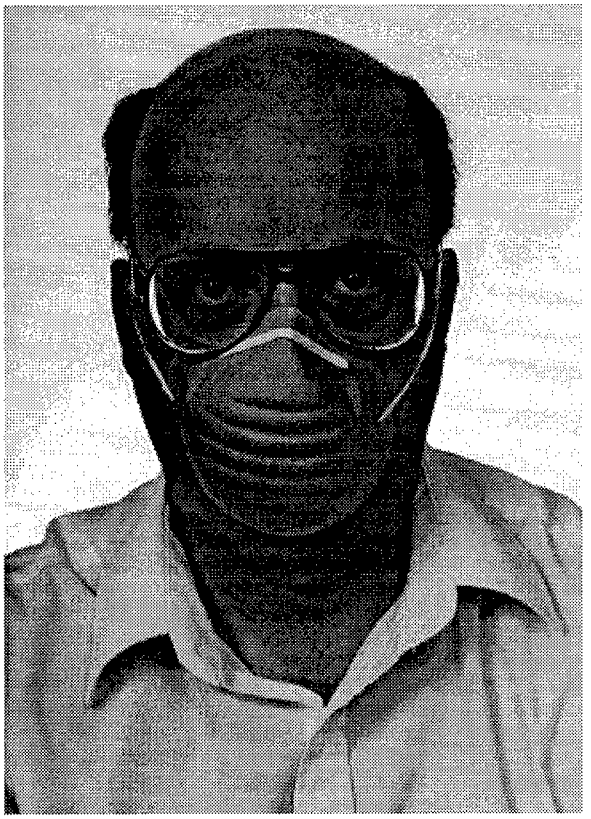

Table 1

Precept Comfort Cone Fluid Resistant Surgical Mask No. 65-3333						
	Protection Factors*					
	Volunteer #					
	1	2	3	4	5	Mean
normal	2.3	1.6	3.3	3.1	1.9	2.4
taped	2.8	1.6	3.2	3.2	2.7	2.7
Comments: This is a blue, cone shaped surgical mask. It was not designed for, nor does it provide protection against aerosolized infectious materials. This mask was also tested with the edges taped to the skin with surgical tape to eliminate leakage from the edge of the mask.						

*Note: The protection factors noted here are based on a comparison of particle counts inside the mask versus those outside the mask during testing with volunteers. With a protection factor of 3, for example, 1 in every 3 particles present will penetrate the mask. With a protection factor of 100, only 1 in 100 particles will penetrate.

Figure 2

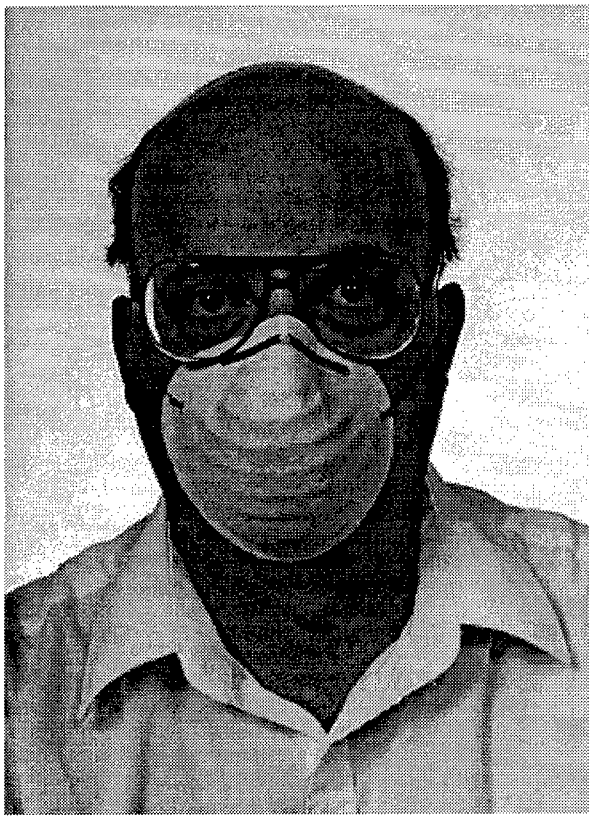

Table 2

3M Non-Toxic Particle Mask No. 8500						
	Protection Factors*					
	Volunteer #					
	1	2	3	4	5	Mean
normal	3.2	2.8	2.7	3.2	3	3
taped	3.8	3.8	3.3	3.1	3.5	3.5

Comments: This mask is similar to commonly available hardware store dust masks. It was not designed for, nor would it provide protection against aerosolized infectious materials. This mask was also tested with the edges taped to the skin with surgical tape to eliminate leakage from the edge of the mask.

*Note: The protection factors noted here are based on a comparison of particle counts inside the mask versus those outside the mask during testing with volunteers. With a protection factor of 3, for example, 1 in every 3 particles present will penetrate the mask. With a protection factor of 100, only 1 in 100 particles will penetrate.

Figure 3

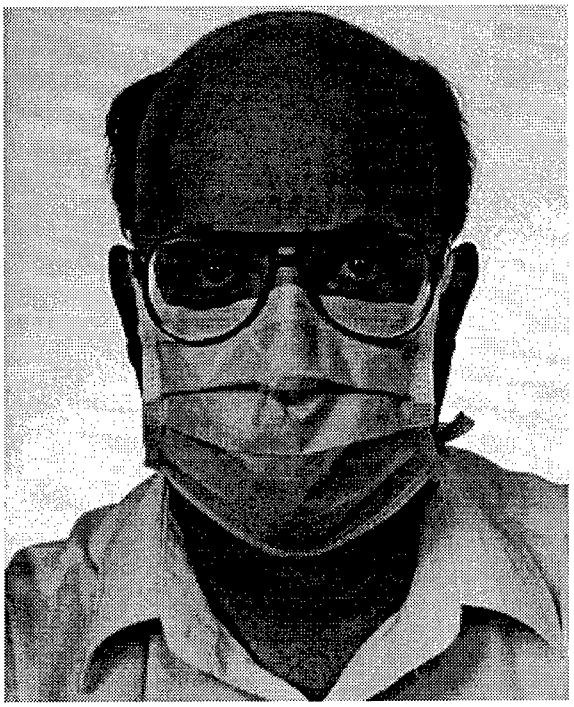

Table 3

Tecnol Classic Surgical Mask No. 48200						
	Protection Factors*					
	Volunteer #					
	1	2	3	4	5	Mean
normal	4.9	3.3	2.1	2.1	5.6	3.6
taped	9.3	4.4	4.8	5.3	7	6.2

Comments: This is the classic style of surgical mask. It was not designed for, nor does it provide protection against aerosolized infectious materials. This mask was also tested with the edges taped to the skin with surgical tape to eliminate leakage from the edge of the mask.

*Note: The protection factors noted here are based on a comparison of particle counts inside the mask versus those outside the mask during testing with volunteers. With a protection factor of 3, for example, 1 in every 3 particles present will penetrate the mask. With a protection factor of 100, only 1 in 100 particles will penetrate.

Figure 4

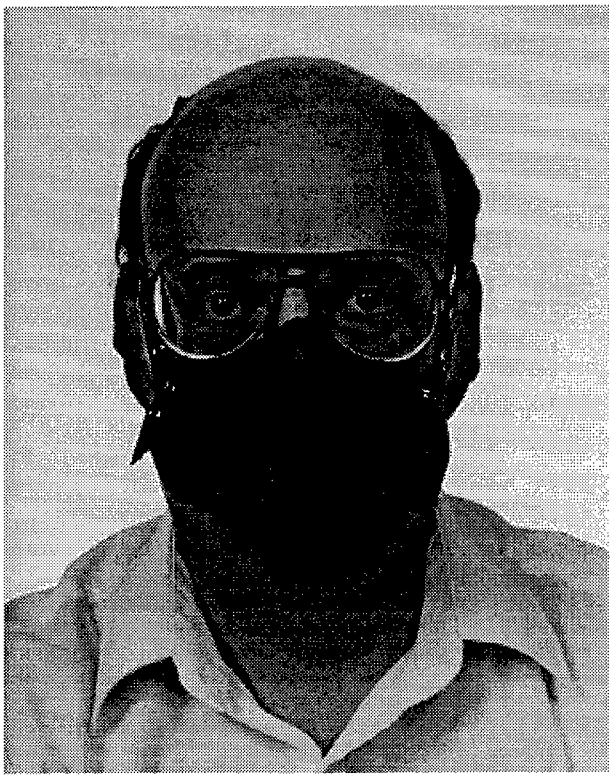

Table 4

Military facelet NBC L1A1 NSN 4240-00-226-3109					
Protection Factors*					
Volunteer #					
1	2	3	4	5	Mean
4.5	7.7	3.6	7.1	4.4	5.5
Comments: This facelet was intended for protection against chemical vapours. It was not designed for, nor does it provide protection, against aerosolized infectious materials.					

*Note: The protection factors noted here are based on a comparison of particle counts inside the mask versus those outside the mask during testing with volunteers. With a protection factor of 3, for example, 1 in every 3 particles present will penetrate the mask. With a protection factor of 100, only 1 in 100 particles will penetrate.

Figure 5

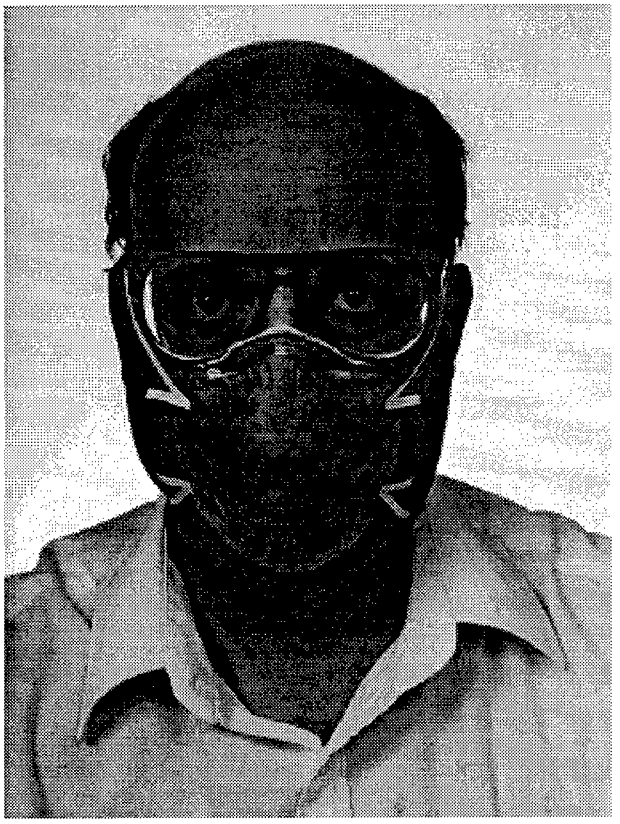

Table 5

3M Nuisance Level Acid Gas Respirator No. 9915						
	Protection Factors*					
	Volunteer #					
	1	2	3	4	5	Mean
normal	19	6.9	32	7.7	16	16.3
taped	39	9.3	45	24	34	30.3

Comments: This mask provides somewhat greater protection against particulates than surgical masks or lower quality dust masks. It was not designed for, nor does it provide protection against aerosolized infectious materials. This mask was also tested with the edges taped to the skin with surgical tape to eliminate leakage from the edge of the mask.

*Note: The protection factors noted here are based on a comparison of particle counts inside the mask versus those outside the mask during testing with volunteers. With a protection factor of 3, for example, 1 in every 3 particles present will penetrate the mask. With a protection factor of 100, only 1 in 100 particles will penetrate.

Figure 6

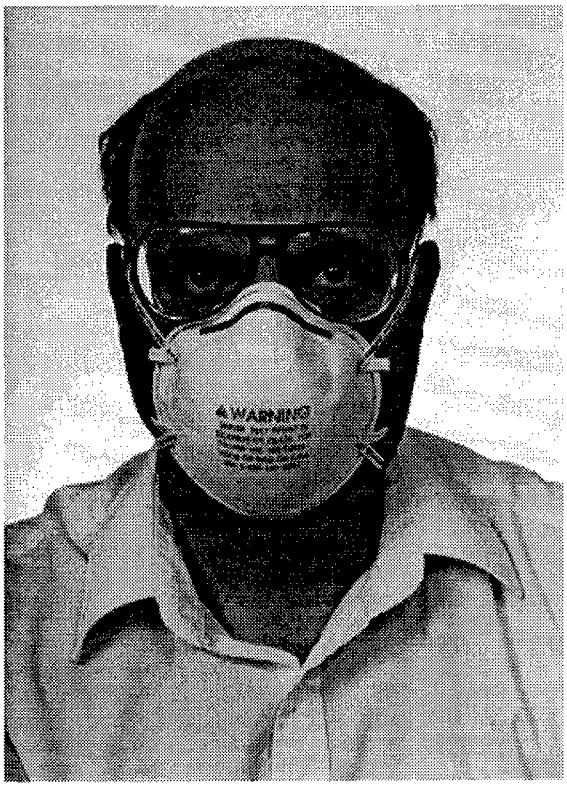

Table 6

3M Dust Mist Respirator No. 9900						
	Protection Factors*					
	Volunteer #					
	1	2	3	4	5	Mean
normal	36	9.3	39	5	10	19.9
taped	46	9.3	73	8.3	12	29.7

Comments: This mask provides somewhat greater protection against particulates than surgical masks or lower quality dust masks. It was not designed for, nor does it provide protection, against aerosolized infectious materials. This mask was also tested with the edges taped to the skin with surgical tape to eliminate leakage from the edge of the mask.

*Note: The protection factors noted here are based on a comparison of particle counts inside the mask versus those outside the mask during testing with volunteers. With a protection factor of 3, for example, 1 in every 3 particles present will penetrate the mask. With a protection factor of 100, only 1 in 100 particles will penetrate.

Figure 7

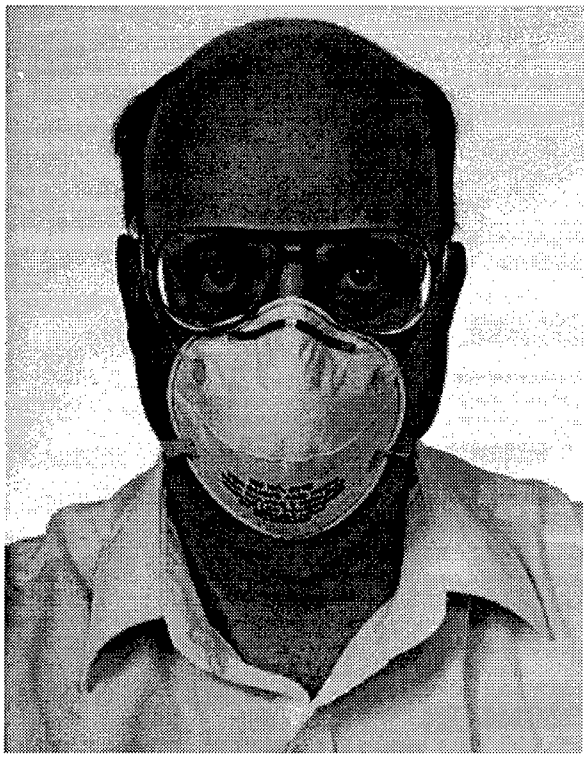

Table 7

3M Dust and Mist Respirator No. 8710						
	Protection Factors*					
	Volunteer #					
	1	2	3	4	5	Mean
normal	20	12	21	9.4	42	20.9
taped	31	24	25	27	43	30
Comments: This mask provides somewhat greater protection against particulates than surgical masks or lower quality dust masks. It was not designed for, nor does it provide protection, against aerosolized infectious materials. This mask was also tested with the edges taped to the skin with surgical tape to eliminate leakage from the edge of the mask.						

*Note: The protection factors noted here are based on a comparison of particle counts inside the mask versus those outside the mask during testing with volunteers. With a protection factor of 3, for example, 1 in every 3 particles present will penetrate the mask. With a protection factor of 100, only 1 in 100 particles will penetrate.

Figure 8

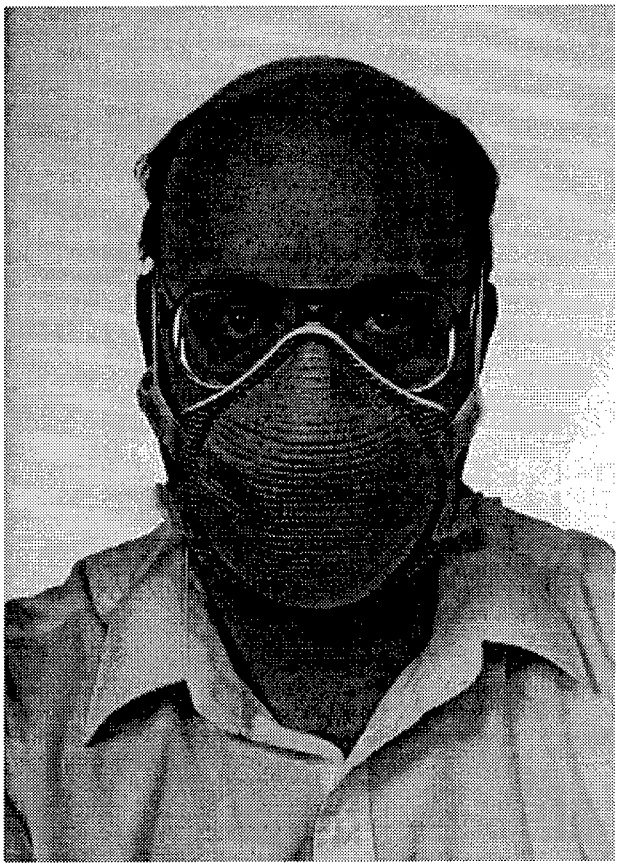

Table 8

Uvex Better Breathing Respirators						
	Protection Factors*					
	Volunteer #					
	1	2	3	4	5	Mean
Size L	375	1110	158	1210	1170	804
Comments: This is a purple, cone shaped type of HEPA (High Efficiency Particulate) filter mask with a formed inner liner that allows a good seal to the face. With a proper fit (eg. Volunteers 2, 4 and 5) it provides excellent protection for this type of mask. The absence of an exhalation port made it less comfortable than the 3M No. 9970 in the opinion of the volunteers. This type of mask is suitable for protection against aerosolized infectious material.						

*Note: The protection factors noted here are based on a comparison of particle counts inside the mask versus those outside the mask during testing with volunteers. With a protection factor of 3, for example, 1 in every 3 particles present will penetrate the mask. With a protection factor of 100, only 1 in 100 particles will penetrate.

Figure 9

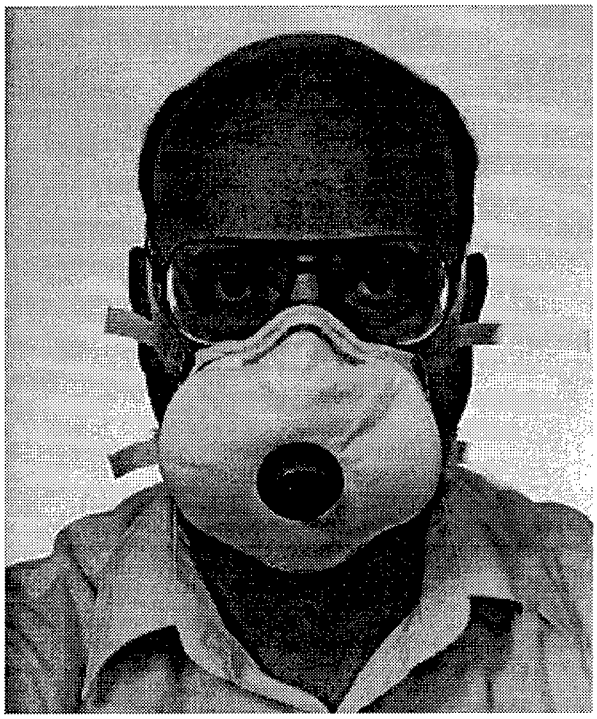

Table 9

3M High Efficiency Respirator with exhalation port No. 9970						
	Protection Factors*					
	Volunteer #					
	1	2	3	4	5	Mean
Size M	168	1540	26	211	2360	861
Size L	441	91	244	159	98	207

Comments: This is a white HEPA (High Efficiency Particulate) filter mask with a purple coloured exhalation port and a formed inner liner that allows a good seal to the face. With a proper fit it provides excellent protection for this type of mask. In overall terms of cost, protection and comfort it provides the best alternative to the C4 among the masks tested.

*Note: The protection factors noted here are based on a comparison of particle counts inside the mask versus those outside the mask during testing with volunteers. With a protection factor of 3, for example, 1 in every 3 particles present will penetrate the mask. With a protection factor of 100, only 1 in 100 particles will penetrate.

Figure 10

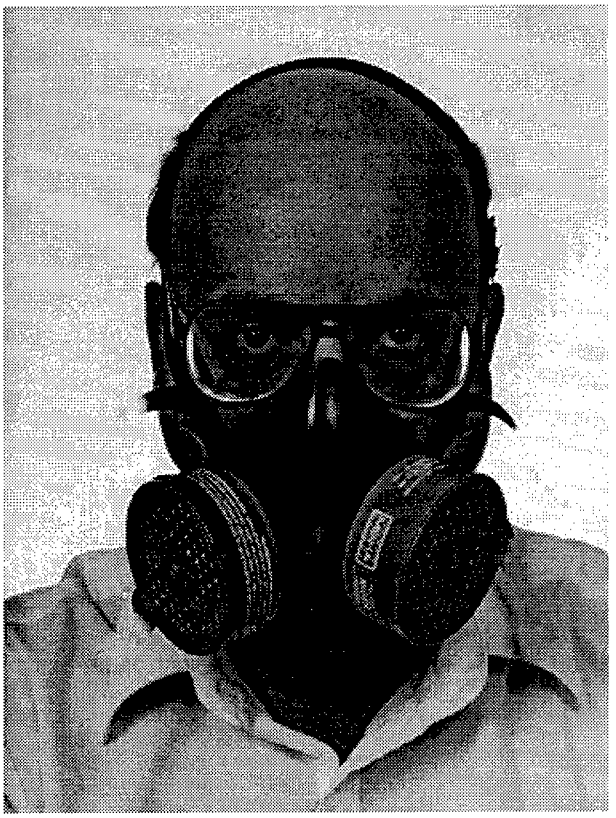

Table 10

Dual Cartridge Respirator Half mask, Silicone						
	Protection Factors*					
	Volunteer #					
	1	2	3	4	5	Mean
Size M	578	3760	933	23600	427	5860
Size S	262	338	3.8	2180	3.3	557
Comments: This mask also provides excellent protection against aerosolized infectious material, although at greater cost than the 3M No. 9970. The visual appearance of the mask would be less threatening than the C4, but more than the 3M mask.						

*Note: The protection factors noted here are based on a comparison of particle counts inside the mask versus those outside the mask during testing with volunteers. With a protection factor of 3, for example, 1 in every 3 particles present will penetrate the mask. With a protection factor of 100, only 1 in 100 particles will penetrate.

Figure 11

Table 11

Canadian Forces C4 Mask					
Protection Factors*					
Volunteer #					
1	2	3	4	5	Mean
21500	38500	22000	21500	14200	23540
Comments: The C4 mask is capable of protecting an individual even in the face of high concentrations of aerosolized infectious material as might be encountered in a Biological warfare (BW) attack. Its use in other types of non-BW situations, eg. Contingency operations dealing with civilians or refugees may be inappropriate. Civilians may consider the mask visually threatening or frightening, and the degree of protection it affords will likely far exceed the risk in non-BW operations.					

*Note: The protection factors noted here are based on a comparison of particle counts inside the mask versus those outside the mask during testing with volunteers. With a protection factor of 3, for example, 1 in every 3 particles present will penetrate the mask. With a protection factor of 100, only 1 in 100 particles will penetrate.

Table 12: Comparison of the Protection Factors observed in the masks tested

Mask Type		Protection Factors		
		Range	Mean	% Protection
3M Non-Toxic Particle Mask No. 8500	untaped	2.7 to 3.2	3	67
	taped	3.1 to 3.8	3.5	71
3M Dust and Mist Respirator No. 8710	untaped	12 to 42	20.9	95
	taped	24 to 43	30	96.7
Tecnol Classic Surgical Mask No. 48200	untaped	2.1 to 5.6	3.6	72
	taped	4.4 to 9.3	6.2	84
Canadian Forces C4 Mask		14200 to 38500	23500	99.996
Precept Comfort-Cone Fluid Resistant Surgical Mask No.65-3333	untaped	1.6 to 3.3	2.4	58
	taped	1.6 to 3.2	2.7	63
3M Nuisance Level Acid Gas Respirator No. 9915	untaped	6.9 to 32	16.3	94
	taped	9.3 to 39	30.3	96.7
3M Dust/Mist Respirator 9900	untaped	5 to 36	19.9	95
	taped	9.3 to 46	29.7	96.6
Uvex Better Breathing Respirators.	Size L	158 to 1170	804	99.9
Dual Cartridge Respirator Half Mask, Silicone.	Size M	427 to 23600	5860	99.98
	Size S	3.8 to 2180	557	99.8
3M High Efficiency Respirator with exhalation port. No. 9970	Size M	211 to 2360	1370	99.93
	Size L	244 to 441	343	99.7
Military facelet NBC L1A1 NSN 4240-00-226-3109		3.6 to 7.7	5.5	82

Note: The protection factors noted here are based on a comparison of particle counts inside the mask versus those outside the mask during testing with volunteers. With a protection factor of 3, for example, 1 in every 3 particles present will penetrate the mask. With a protection factor of 100, only 1 in 100

Table 13: Summary of Protection Factors for 3M No. 9970

Mask Size	# Volunteers	Protection Factors
Medium	15	Range: 44 to 2360 Average: 451
Large	7	Range: 29-609 Average: 257

*Note: The protection factors noted here are based on a comparison of particle counts inside the mask versus those outside the mask during testing with volunteers. With a protection factor of 3, for example, 1 in every 3 particles present will penetrate the mask. With a protection factor of 100, only 1 in 100 particles will penetrate.

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There are an increasing number of possible scenarios for the Canadian Forces where protection from a biological threat is required. These scenarios extend beyond the threat of biological warfare and include contingency operations, such as peace-keeping and humanitarian operations. Many of the diseases we consider as potential biological warfare threats exist as endemic diseases in many parts of the world. While the Canadian Forces C4 mask would provide protection against aerosolized infectious material in these situations, the use of the mask could degrade operational performance and the degree of protection provided could be far in excess of the risk. In this study we have assessed a variety of commercially available alternatives to the C4 that could provide an appropriate degree of protection relative to the risks involved, while presenting a lower logistical and operational burden. Overall, the 3M High Efficiency Respirator with exhalation port no. 9970 appears to be an ideal alternative to the C4 in such situations.

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C4 Mask
3M High Efficiency Respirator
HEPA
Respiratory Protection
Contingency Operations